FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P.
1300 I STREET, N.W.
WASHINGTON, DC 20005-3315

202•408•4000
FACSIMILE 202•408•4400

BRUSSELS OFFICE:
AVENUE LOUISE 326, BOX 37
1050 BRUSSELS, BELGIUM
TELEPHONE 011•322•646•0353
FACSIMILE 011•322•646•2135

WRITER'S DIRECT DIAL NUMBER

(202) 408-4096

TOKYO OFFICE:
TORANOMON NO. 45 MORI BUILDING
1-5, TORANOMON 5-CHOME
MINATO-KU, TOKYO 105, JAPAN
TELEPHONE 011•813•3431•6943
FACSIMILE 011•813•3431•6945

A $

September 24, 1997

ATTORNEY DOCKET NO.: 06394.0022

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

New U.S. Patent Application
Title: REFLECTIVE-TYPE LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR MAKING THE SAME
Inventor: Yong Beom KIM

Sir:

We enclose the following papers for filing in the United States Patent and Trademark Office in connection with the above patent application.

1. Application - 20 pages, including 4 independent claims and 42 claims total.

2. Drawings - 9 sheets of formal drawings, containing 13 figures.

3. Declaration and Power of Attorney.

4. Recordation Form Cover Sheet and Assignment to LG ELECTRONICS INC.

5. Certified copies of Korean Application Nos. 1997-17766 and 1997-17767, filed May 9, 1997.

6. A check for $1,634.00 representing a $770.00 filing fee, $484.00 for extra claims fee, $260.00 for multiple dependent claims fee, $80.00 for independent claims fee and $40.00 for recording the Assignment.

Applicant claims the right to priority based on Korean Application Nos. 1997-17766 and 1997-17767, filed May 9, 1997.

Please accord this application a serial number and filing date and record and return the Assignment to the undersigned.

The Commissioner is hereby authorized to charge any additional filing fees due and any other fees due under 37 C.F.R. § 1.16 or § 1.17 during the pendency of this application to our Deposit Account No. 06-0916.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW,
GARRETT & DUNNER, L.L.P.

By: Arthur S. Garrett 20,338 for
Ernest F. Chapman
Reg. No. 25,961

EFC/FPD/rgm
Enclosures

BACKGROUND OF THE INVENTION

A. Field of the Invention

This invention relates to a liquid crystal display device and, more particularly, a reflective-type liquid crystal display device.

B. Description of the prior art

Liquid crystal display devices ("LCDs") can be classified into TN (Twisted Nematic) type, GH (Guest Host) type, ECB (Electrically Controlled Birefringence) type and OCB (Optically Compensated Birefringence) type and so on, in accordance with the driving mode.

Recently, the TN-LCDs have been extensively used in devices such as the portable personal computer, measurement apparatus and the like. However, TN-LCDs, while having a number of advantages, also have the disadvantages of a narrow viewing angle and low response time.

When a voltage is applied to a liquid crystal cell, the birefringence index of the liquid crystal cell changes as the alignment of the liquid crystal molecules changes corresponding to the dielectric anisotropy of the liquid crystal.

A mode, called the ECB mode, induces a change in the light transmission to change the birefringence index of the liquid crystal cell. HAN (Hybrid-Aligned Nematic) mode LCDs are representative of the ECB-LCDs. HAN mode LCD's have the advantages of having a low driving voltage and the ability to display full color well. Studies of the HAN mode have been

widely advanced in OCB mode LCDs using the optical change of the liquid crystal cell as well as ECB mode LCDs.

FIG. 1 is drawing showing a schematic structure of a traditional reflective-type OCB-LCD (hereinafter ROCB-LCD) using HAN mode. The ROCB-LCD includes a first substrate 11 having a reflective electrode 16, a second substrate 12 onto which a biaxial retardation film 14 and a polarizer 15 are formed, and a liquid crystal layer 10 between first substrate 11 and second substrate 12. Movement of the liquid crystal display device having above-discussed structure will be explained in detail.

After incident light (not shown) passes through polarizer 15, biaxial retardation film 14, second substrate 12, and the liquid crystal layer 10 to compensate for phase changes due to viewing angles of a user, the incident light is reflected by reflective electrode 16 formed on first substrate 11. It is thereby possible for the user to achieve a desired image.

The above traditional HAN mode ROCB-LCDs, unlike the TN-LCD, have no restrictive condition to satisfy the first minimum condition regarding the viewing angle problems, i.e.,$\Delta n \bullet d \geq \lambda/2$(where Δn is the refractive index, d is a thickness of the liquid crystal layer, and λ is the wavelength of light), and since it is a SB(semi-bend) structure, there is no phase change of splay/bend. In the above HAN mode ROCB-LCD, a front scattering film can be attached on the polarizer 15, or a plurality of convex portions can be formed on the refractive electrode 16 in order to achieve a wide viewing angle.

The liquid crystal used in traditional HAN mode ROCB-LCDs has different light paths according to the y-z plane (including director) and x-z plane. In order to compensate the phase difference corresponding to the change in viewing angle of the user, the difference in the light path must be compensated by using a biaxial retardation film which has three reflective indices at the x, y, and z axes.

Therefore, the HAN mode ROCB-LCD using the biaxial retardation film has many advantages over the TN-LCD. However, gray is introduced by the decreased retardation of the liquid crystal when a voltage is applied to it. Further, the use of biaxial retardation films is disadvantageous due to manufacturing cost and the need to satisfy the complex condition demanded by the user.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide a HAN mode ROCB-LCD having a wide viewing angle and a method for making the same by using a negative uniaxial optical compensation film or positive uniaxial optical compensation film.

It is another object of the present invention to divide a pixel into two domains in order to effectively use the uniaxial optical compensation films.

Additional objects and advantages of the invention will be set forth in part in the description that follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and

advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

To achieve the objects and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention includes first and second substrates, a liquid crystal layer between the first and second substrates, and at least one uniaxial optical compensation film on the second substrate.

According to another aspect of the invention, the invention includes first and second substrates. a liquid crystal layer between the first and second substrates, at least one uniaxial optical compensation film on the second substrate, and a first alignment layer over the first substrate, the first alignment layer having a plurality of alignment directions.

A method according to the invention includes providing first and second substrates, providing a liquid crystal layer between the first and second substrates, providing at least one uniaxial optical compensation film on the second substrate, and forming a first alignment layer over the first substrate, the first alignment layer having a plurality of alignment directions.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate the embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic showing the traditional structure of a HAN mode ROCB-LCD.

FIG. 2 is a schematic showing the structure of an LCD using two positive uniaxial optical compensation films according to a first embodiment of the present invention.

FIG. 3 is a schematic showing the structure of an LCD using one negative uniaxial optical compensation film according to a second embodiment of the present invention.

FIG. 4 is a schematic showing the structure of an LCD using a uniaxial optical compensation film according to a third embodiment of the present invention, in which one pixel is divided into two domains .

FIGs. 5a and 5b are graphs showing the change in viewing angle characteristic according to the change in other coefficients at an azimuth angle 45^0 (the direction of liquid crystal director) with a phase difference of 40nm between two positive uniaxial optical compensation films.

FIGs. 6a and 6b are graphs showing the change in viewing angle characteristic according to the change in other coefficients at an azimuth angle 135^0 (the perpendicular direction of liquid crystal director) with a phase difference of 40nm between two positive uniaxial optical compensation films.

FIGs. 7a and 7b are graphs showing the change In viewing angle characteristic according to the change in other coefficients at an azimuth

angle 45° with a film thickness of 50um.

FIGs. 8a and 8b are graphs showing the change in viewing angle characteristic according to the change in other coefficients at an azimuth angle 135° with a film thickness of 40um.

FIG. 9 is a graph showing the term of the ideal viewing angle characteristic represented by two positive uniaxial optical compensation films.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made In detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

FIG.2 is a schematic showing the structure of an LCD using two positive uniaxial optical compensation films according to a first embodiment of the present invention. As shown, the LCD in accordance with this invention includes a first substrate 111 having a reflective electrode 116, a second substrate 112 on which two positive uniaxial optical compensation films 114 and 115 and a polarizer 117 are formed, and a liquid crystal layer 110 between the first substrate 111 and the second substrate 112.

After incident light (not shown) passes through polarizer 117, the two positive uniaxial optical compensation films 114 and 115, second substrate

112, and liquid crystal layer 110, the incident light is reflected by reflective electrode 116 formed on first substrate 111. The reflected light then returns through the opposite path, whereby it is possible for a user to achieve a desired image. The two positive uniaxial optical compensation films compensate the phase difference which the user realizes at a direction normal to the substrate and at a direction corresponding to the change in viewing angle.

A method for manufacturing the LCD includes forming reflective electrode 116 by the deposit of opaque metal such as A1 on first substrate 111, forming a first alignment layer (not shown) on reflective electrode 116 by photo-alignment or mechanical alignment such as rubbing, forming films114 and 115 and polarizer 117 on second substrate 112, forming a second alignment layer (not shown), and forming liquid crystal layer 110 between first substrate 111 and second substrate 112. Alignment conditions of the alignment layers are properly controlled according to the characteristics of the liquid crystal and desired term, with the second alignment layer formed in the same manner .

The relationship between phase difference and reflective index of two positive uniaxiai optical compensation films is satisfied by $\Delta n \bullet d = |(\Delta n_1 \bullet d_1) - (\Delta n_2 \bullet d_2)| = [(n_{x1} - n_{y1}) - (n_{x2} - n_{y2})] \bullet d$, where Δn is a refractive index, d is a film thickness, n_{x1} and n_{x2} represent extra ordinary refractive indices; and n_{y1} and n_{y2} represent ordinary refractive indices. Preferably, each ordinary refractive index of the two films is the same and the phase difference between the two

films is low.

FIG. 3 is a schematic showing the structure of an LCD using one negative uniaxial optical compensation film according to a second embodiment of the present invention. As shown, the LCD in accordance with this embodiment includes a first substrate 211 having a reflective electrode 216, a second substrate 212 on which one negative uniaxial optical compensation film 214 and a polarizer 215 are formed, and a liquid crystal layer 210 between first substrate 211 and second substrate 212.

In the LCD having above-mentioned structure, after incident light (not shown) passes through polarizer 215, negative uniaxial optical compensation film 214, second substrate 212, and liquid crystal layer 210, the incident light is reflected by reflective electrode 216 formed on first substrate 211. Further, the reflected light returns in the opposite direction, whereby it is possible for user to achieve desired image. The negative uniaxial optical compensation film compensates the phase difference which the user realizes at a direction normal to the substrate and at a direction corresponding to the change in viewing angle.

A method for manufacturing the LCD proceeds in the same manner as for the first embodiment except one negative uniaxial optical compensation film is used instead of two positive uniaxial optical compensation films.

In the negative uniaxial optical compensation film, the relationship of each refractive index is satisfied by $n_x=n_y=n_0$, $n_z=n_e$ and $n_0>n_e$, where n_x is a refractive index in the x-direction, n_y is a refractive index in the y-direction.

The light path difference of the liquid crystal layer corresponding to the change in polar angle can thus be overcome. Also, in the case where the surface of the reflective electrode forms a plurality of convex portions in order to increase brightness, the alignment direction of the alignment layer should be formed perpendicular to the substrate to achieve a wide viewing angle.

FIG. 4 is a schematic showing the structure of an LCD using a uniaxial optical compensation film according to a third embodiment of this invention, in which a pixel is divided two domains. The LCD includes a first substrate 311 having a reflective electrode 316, a second substrate 312 on which a uniaxial optical compensation film 314 (negative or positive type) and a polarizer 315 are formed, and a liquid crystal layer 310 between first substrate 311 and second

substrate 312.

A method for manufacturing the LCD includes the steps of forming a reflective electrode 316 by the deposit of an opaque metal such as Al on first substrate 311, forming a first alignment layer (not shown) on reflective electrode 316 by photo-alignment with exposure to ultraviolet (UV) light, in which the alignment direction of the liquid crystal molecule by the first alignment layer is divided into two directions, x and y, wherein after the y(or x)-direction alignment process is executed, the x(or y)-direction alignment process is executed using a mask. Alignment conditions of the alignment layers are properly controlled according to the characteristics of the liquid crystal and the desired term. The uniaxial optical compensation film 314 and

polarizer 315 are then formed on second substrate 312, and a second alignment layer (not shown) is formed by the same manner described above. As before, alignment conditions of the alignment layers are properly controlled according to the characteristics of the liquid crystal and the desired term. Finally, liquid crystal layer 310 if formed between first substrate 311 and second substrate 312.

In the above-mentioned process, it is possible to expose UV light to at least one surface of the substrates using non-polarized light or partially polarized light. It is also possible to form the alignment direction using a mechanical method, such as rubbing, or by using a combination of photo alignment and mechanical method. For example, the alignment direction of the first alignment layer can be formed perpendicularly using photosensitive material, while the alignment direction of the second alignment layer is formed in parallel using the rubbing manner. As a result. a HAN mode ROCB-LCD having a pixel divided into two domains is obtained. Further, the structure of the first and second substrates are interchangeable, and it is possible to obtain the effect of this invention using a perpendicularly or horizontally (or laterally) aligned general polyimide alignment layer.

Hereinafter, preferred results of experiments according to this invention are described in detail with reference to the accompanying drawings.

FIGs. 5a and 5b represent changes in the viewing angle characteristic according to changes in other coefficients wherein an azimuth angle of 45^{0}

and a phase difference($\Delta n \bullet d$) of 40nm are constantly maintained. However, $\Delta n_1(n_{x1}-n_{y1})$ is changed to 0.01, 0.015, and 0.02, and the thickness of the two positive uniaxial optical compensation films is changed to 35, 50, and 90.

FIGa. 6a and 6b represent changes in the viewing angle characteristic according to changes in other coefficients wherein an azimuth angle of 135^0 and a phase difference ($\Delta n \bullet d$) of 40nm are constantly maintained. However, $\Delta n_1(n_{x1}-n_{y1})$ is changed to 0.01, 0.015, and 0.02, and thickness of the two positive uniaxial optical compensation films is changed to 35, 50, and 90.

FIGs. 7a and 7b represent changes in viewing angle characteristic according to changes of other coefficients wherein an azimuth angle of 45^0 and a film thickness of 50um are constantly maintained. However, $\Delta n_1(n_{x1}-n_{y1})$ is changed to 0.002, 0.004, and 0.006 and $\Delta n \bullet d$ is changed to 30, 40, and 50nm. As shown, the viewing angle characteristic is increased corresponding to the increasing level of the two coefficients.

FIGs. 8a and 8b represent changes in viewing angle characteristic according to changes of other coefficients wherein an azimuth angle of 135^0 and a film thickness of 50um are constantly maintained. However, $\Delta n_1(n_{x1}-n_{y1})$ is changed to 0.002, 0.004, and 0.006 and $\Delta n \bullet d$ is changed to 30, 40 and 50nm. As shown, the viewing angle characteristic is decreased corresponding to an increasing value of $\Delta n_1(n_{x1}-n_{y1})$ when $\Delta n \bullet d$ is 50nm .

As a result, only when $\Delta n \bullet d$ is 30-40nm and $\Delta n_1(n_{x1}-n_{y1})$ is 0.005-0.006, a viewing angle larger than 40^0 is achieved. This result is represented in FIG. 9 having a lined region which is the most ideal region.

In the experiment, changes in viewing angle characteristic are observed according to azimuth angle wherein the thickness of the liquid crystal cell is4 5um, pretilt angle is 3-4^0 and direction of liquid crystal director 45^0.

Since the LCD according to the present invention uses uniaxial optical compensation films substituted for traditional biaxial optical compensation films, it is possible to achieve a wide viewing angle characteristic. Moreover, uniaxial films are cheaper and easier to manufacture than biaxial optical compensation films, thus reducing the cost of the LCD.

Furthermore, four domains can be achieved In transmission-type LCDs by dividing a pixel into two domains in accordance with the present invention. As a result, uniform optical characteristic is achieved without regard to the change of viewing angle of the user.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims and their equivalents.

WHAT IS CLAIMED IS:

I. A reflective-type liquid crystal display device comprising :

first and second substrates;

a liquid crystal layer between the first and second substrates; and

at least one uniaxial optical compensation film over the second substrate.

2. The device of claim 1, further comprising a reflective electrode formed over the first substrate.

3. The device of claim I, wherein said at least one uniaxial optical compensation film is negative-type.

4. The device of claim I, wherein said at least one uniaxial optical compensation film is positive-type.

5. The device of claim I, further comprising:

a first alignment layer over the first substrate; and

a second alignment layer over the second substrate.

6. The device of claim 5, wherein said first alignment layer has a first alignment direction, and said second alignment layer has a second alignment direction different than said first alignment direction.

7. The device of claim 6, wherein said first alignment direction is substantially perpendicular to said second alignment direction.

8. A reflective-type liquid crystal display device, comprising:

first and second substrates;

a liquid crystal layer between the first and second substrates ;

at least one uniaxial optical compensation film over the second substrate; and

a first alignment layer having a plurality of first alignment directions over the first substrate.

9. The device of claim 8, wherein said plurality of first alignment directions includes two alignment directions.

10. The device of claim 8, wherein said at least one uniaxial optical compensation film is negative-type.

11. The device of claim 8, wherein said at least one uniaxial optical compensation film is positive-type.

12. The device of claim 8, further comprising a second alignment layer having a second alignment direction over the second substrate.

13. The device of claim 8, wherein said second alignment direction of the second alignment layer is different than said plurality of first alignment directions of the first alignment layer .

14. A method for manufacturing a reflective-type liquid crystal display device, comprising:

providing first and second substrates;

providing a liquid crystal layer between the first and second substrates;

providing at least one uniaxial optical compensation film over the second substrate; and

forming a first alignment layer having a plurality of first alignment directions over the first substrate.

15. The method of claim 14, wherein the uniaxial optical compensation film is negative-type.

16. The method of claim 14, wherein the uniaxial optical compensation film is positive-type.

17. The method of claim 14, wherein said plurality of first alignment directions includes two alignment directions.

18. The method of claim 14, wherein at least two of said plurality of first alignment directions of the first alignment layer are substantially perpendicular to one another.

19. The method of claim 14, wherein at least two of said plurality of first alignment directions of the first alignment layer are parallel to one another.

20. The method of claim 14, wherein said forming a first alignment layer includes exposing said first alignment layer to ultraviolet light to form said plurality of first alignment directions.

21. The method of clalm 14, whereln said formlng a first alignment layer includes rubbing a surface of said first alignment layer to form said plurality of first alignment directions .

22. The method of claim 14, further comprising providing a second alignment layer over the second substrate.

23. The method of claim 22, wherein said providing a second alignment layer includes exposing said second alignment layer to ultraviolet light to form a second alignment direction of said alignment layer.

24. The method of claim 22, wherein said providing a second alignment layer includes rubbing a surface of said second alignment layer to form a second alignment direction of said second alignment layer.

25. The method of claim 22, wherein a second alignment direction of the second alignment layer is different than at least one of said first directions of the first alignment layer.

26. The method of claims 20 or 23, wherein said ultraviolet light is non-polarized.

27. The method of claims 20 or 23, wherein said ultraviolet light is partially polarized.

28. The method of claims 20 or 23, wherein said exposing said first or second alignment layer includes exposing it to said ultraviolet light only once.

29. The method for manufacturing reflective-type liquid crystal display device, comprising:

providing first and second substrates;

providing a liquid crystal layer between the first and second substrates;

providing at least one uniaxial optical compensation film over the second substrate;

forming a first alignment layer over the first substrate;

and

forming a second alignment layer over the second substrate.

30. The method of claim 29, wherein said forming a first alignment layer includes exposing the first alignment layer to Ultraviolet light to form a first alignment direction of the first alignment layer.

31. The method of claim 29, wherein said forming a first alignment layer includes rubbing a surface of the first alignment layer to form a first allgnment dlrectlon of the first alignment layer .

32. The method of claim 29, wherein said forming a second alignment layer includes exposing the second alignment layer to ultraviolet light to form a second alignment direction of the second alignment layer.

33. The method of claim 29, wherein said forming a second alignment layer includes rubbing a surface of the second alignment layer to form a second alignment direction of the second alignment layer.

34 . The method of claims 30 or 32, wherein the ultraviolet light is

non-polarized.

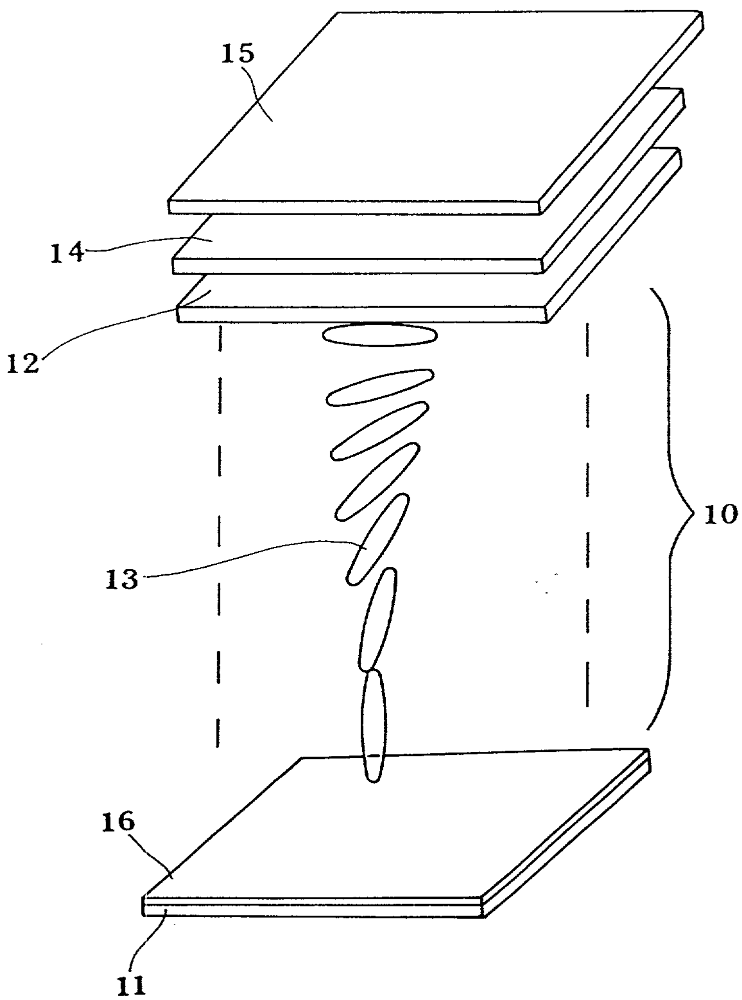
35. The method of claims 30 or 32, wherein the ultraviolet light is partially polarized.

36. The method of clalms 30 or 32, wherein said exposing the first or second alignment layer to ultraviolet light includes exposing it to said ultraviolet light only once.

ABSTRACT OF THE DISCLOSURE

A reflective type liquid crystal display device includes first and second substrates, a liquid crystal layer between the first and second substrates, and at least one uniaxial optical compensation film on the second substrate.

FIG · 1
PRIOR ART



FIG・2

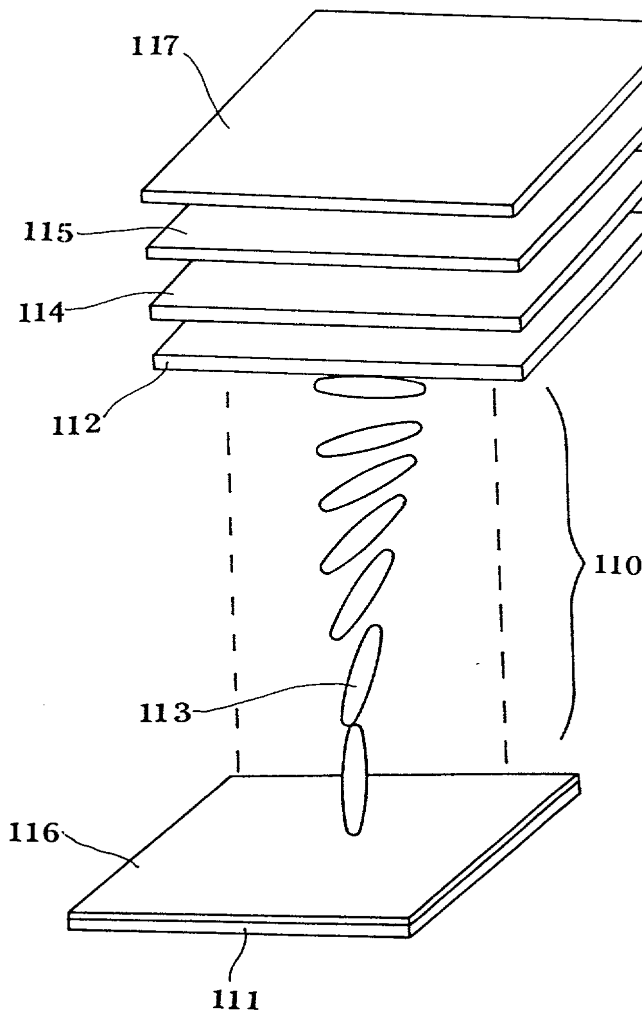


FIG · 3

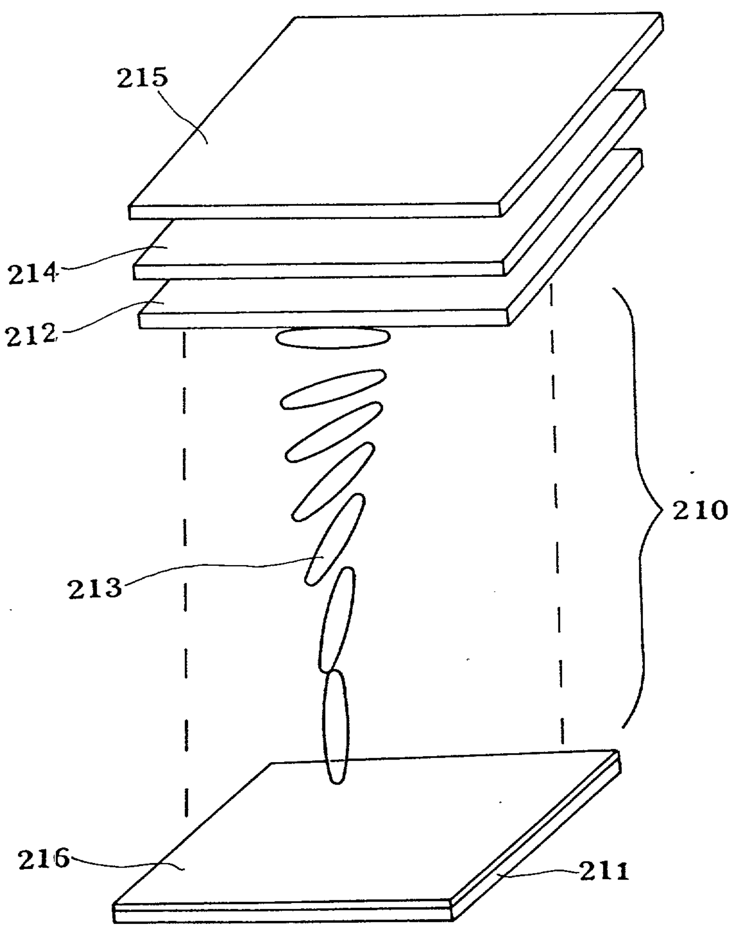


FIG · 4

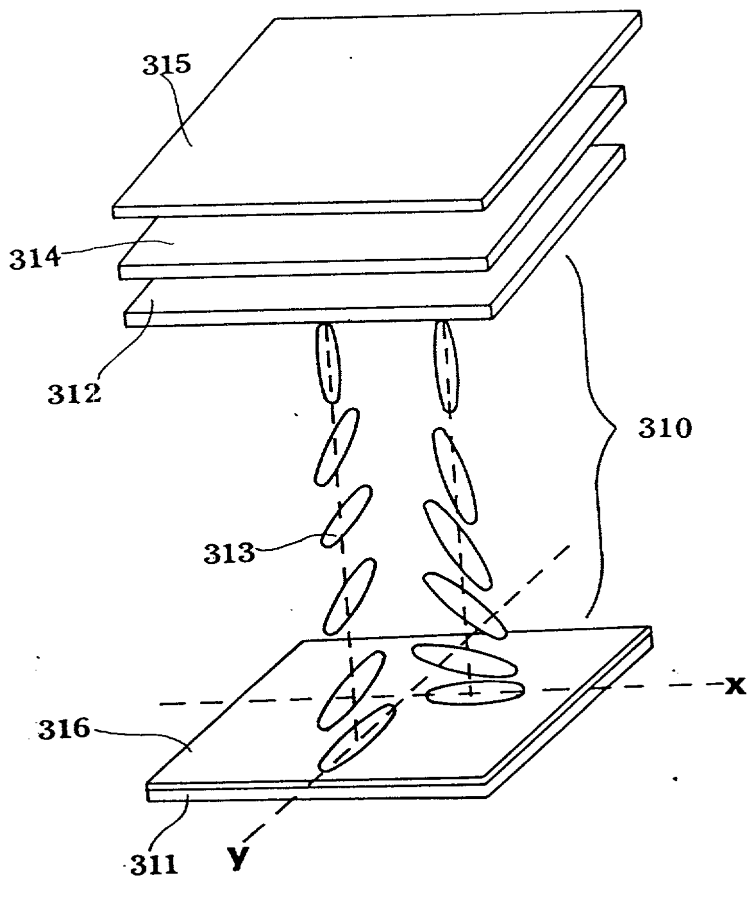


FIG · 5a

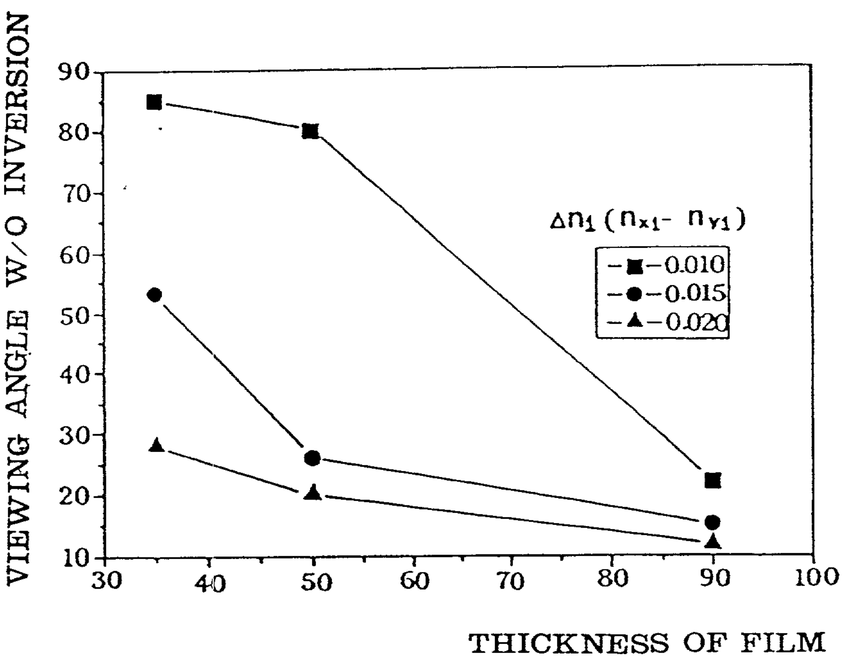

VIEWING ANGLE W/O INVERSION
90
80
70
60
50
40
30
20
10
30
40
50
60
70
80
90
100
THICKNESS OF FILM
Δn1 (nx1- nY1)
-0.010
-0.015
-0.020

FIG · 5b

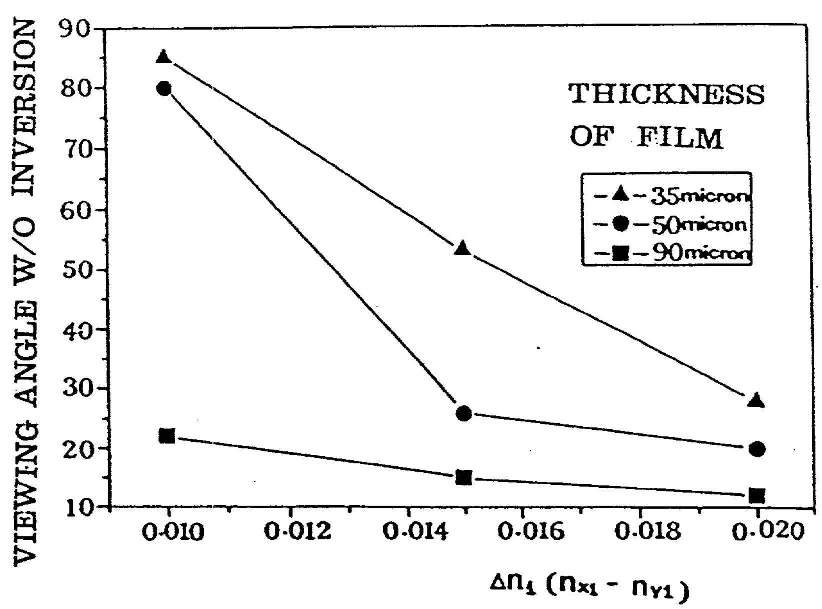
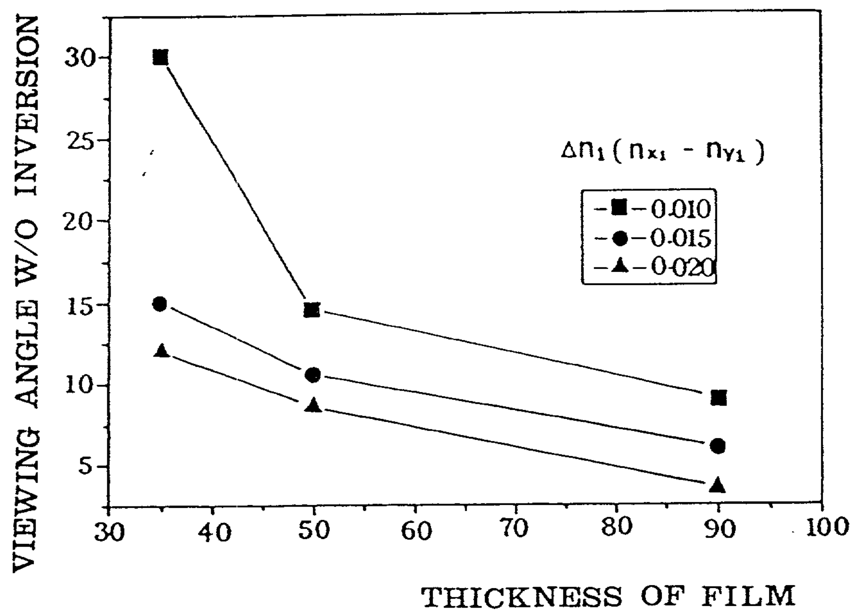
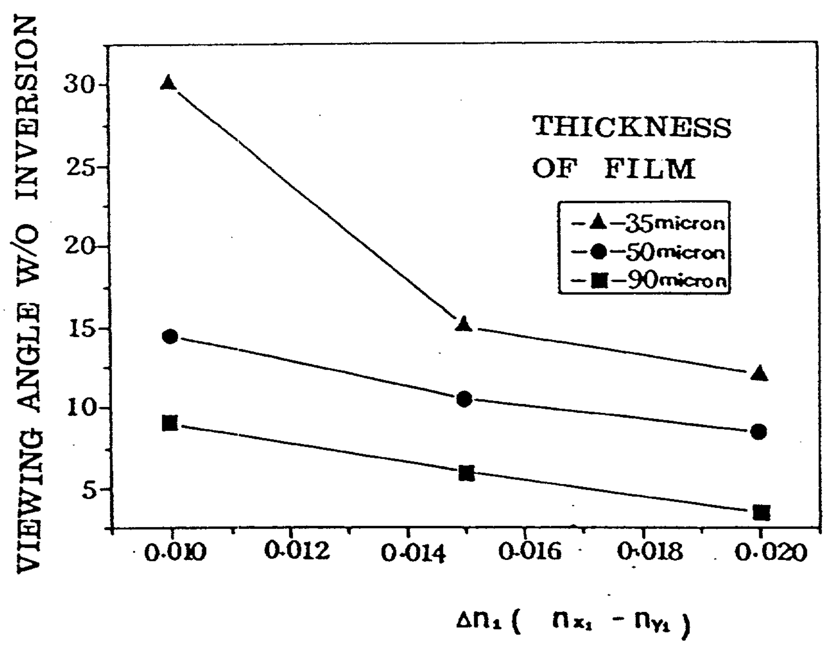

VIEWING ANGLE W/O INVERSION
90
80
70
60
50
40
30
20
10
0.010
0.012
0.014
0.016
0.018
0.020
Δn1 (nx1 - nY1)
THICKNESS
OF FILM
35micron
50micron
90micron

FIG · 6a



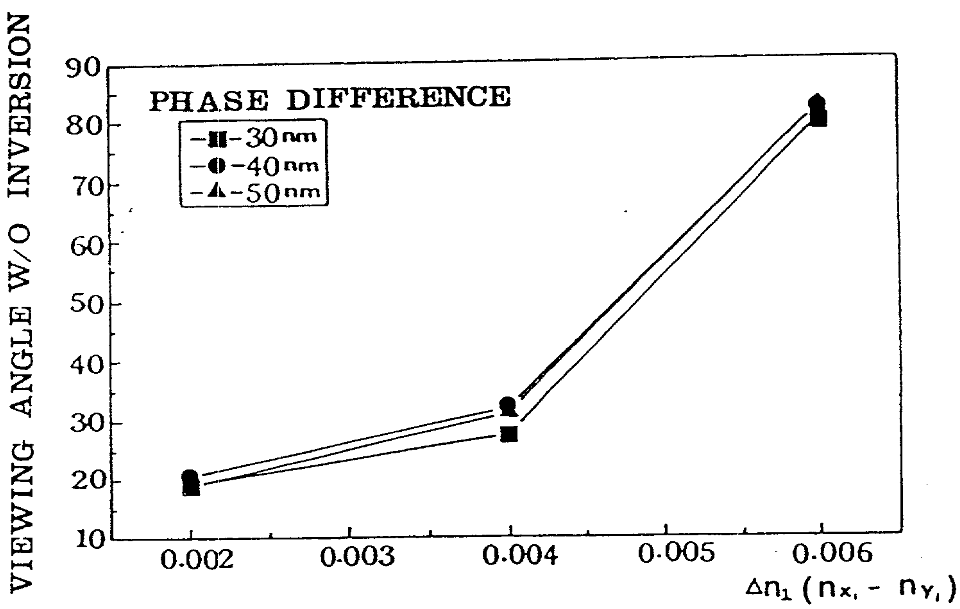
VIEWING ANGLE W/O INVERSION
30
25
20
15
10
5
30
40
50
60
70
80
90
100
THICKNESS OF FILM
Δn1 (nx1 - ny1)
0.010
0.015
0.020

FIG · 6b



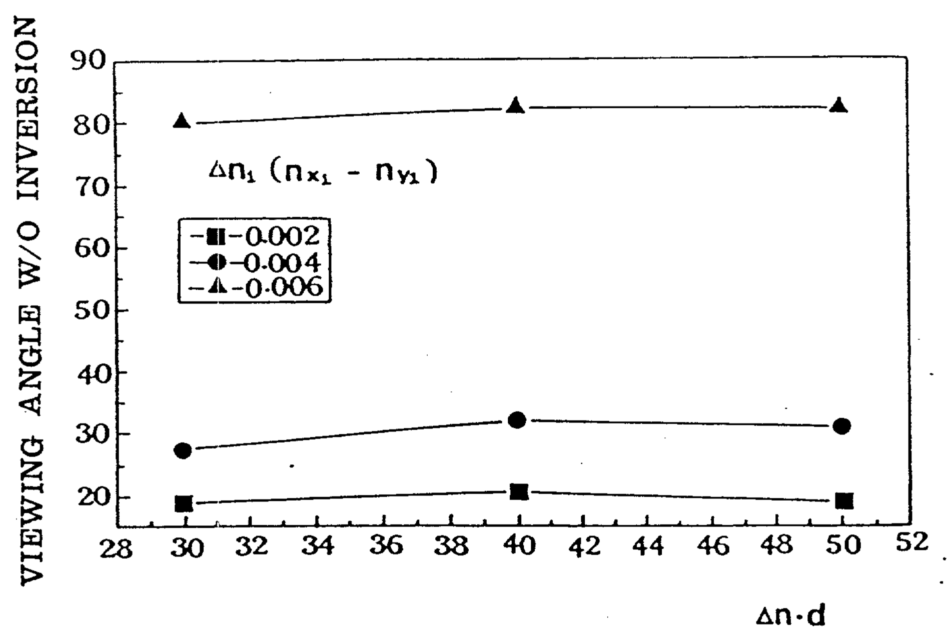
VIEWING ANGLE W/O INVERSION
30
25
20
15
10
5
0.010
0.012
0.014
0.016
0.018
0.020
Δn1 (nx1 - ny1)
THICKNESS OF FILM
35micron
50micron
90micron

FIG · 7a



VIEWING ANGLE W/O INVERSION
PHASE DIFFERENCE
-30nm
-40nm
-50nm
90
80
70
60
50
40
30
20
10
0.002
0.003
0.004
0.005
0.006
Δn1 (nx1 - ny1)

FIG · 7b



VIEWING ANGLE W/O INVERSION
Δn1 (nx1 - ny1)
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-0.004
-0.006
90
80
70
60
50
40
30
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34
36
38
40
42
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46
48
50
52
Δn·d

FIG. 8a

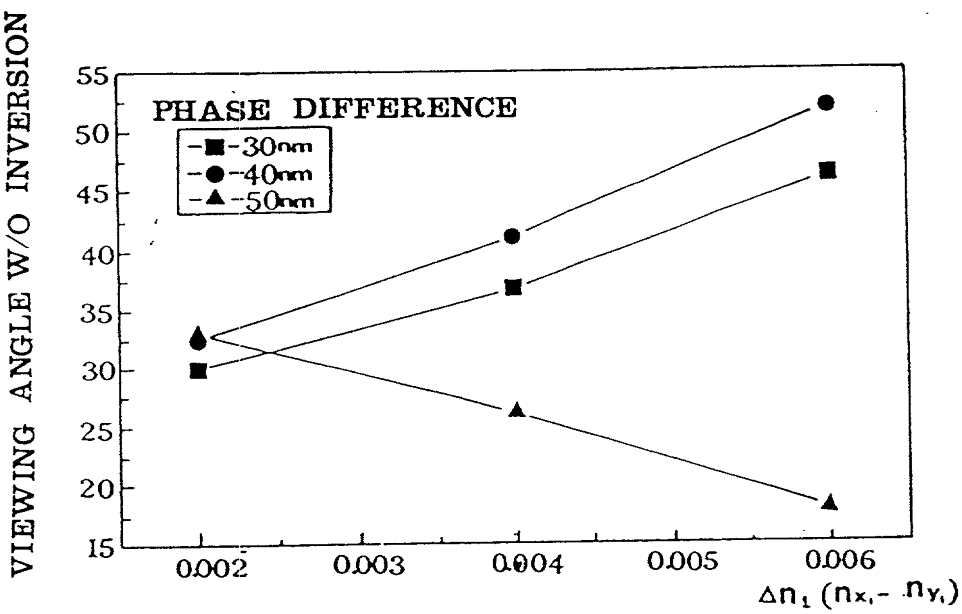
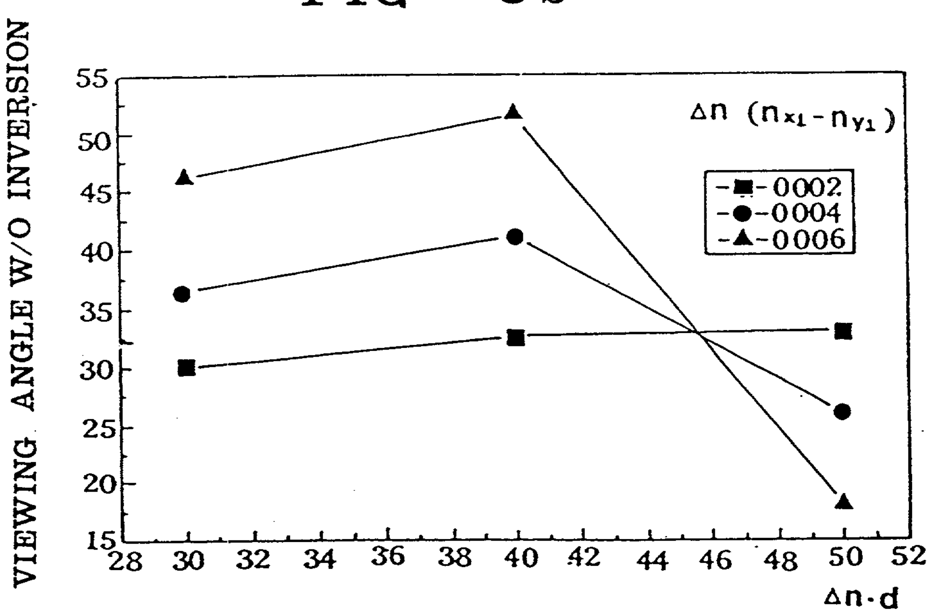

VIEWING ANGLE W/O INVERSION
PHASE DIFFERENCE
-30nm
-40nm
-50nm
55
50
45
40
35
30
25
20
15
0.002
0.003
0.004
0.005
0.006
Δn1 (nx1 - ny1)

FIG. 8b


VIEWING ANGLE W/O INVERSION
Δn (nx1 - ny1)
-0.002
-0.004
-0.006
55
50
45
40
35
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15
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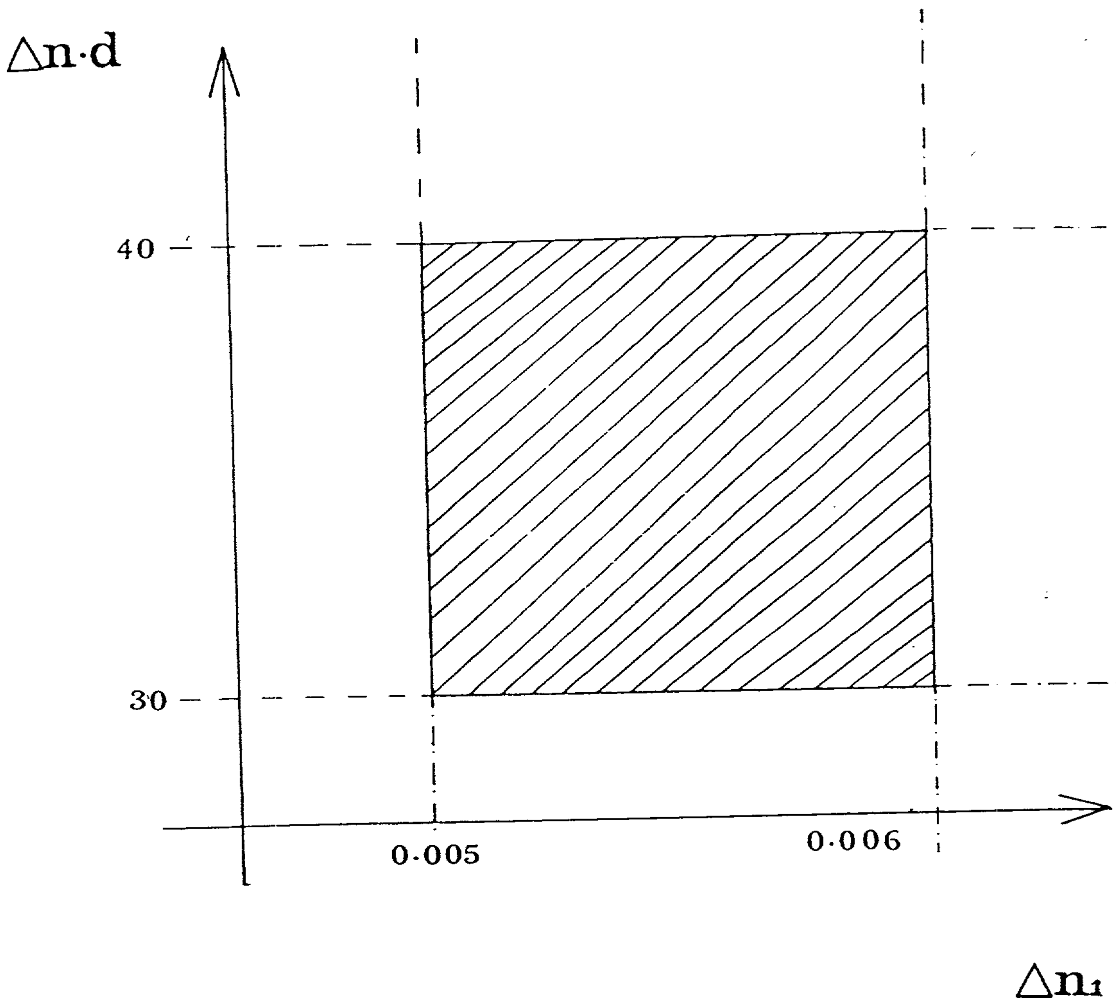
30
32
34
36
38
40
42
44
46
48
50
52
Δn·d

FIG · 9



Attorney Docket No. 06394.0022

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: REFLECTIVE-TYPE LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR MAKING THE SAME

the specification of which ☐ is attached and/or ☐ was filed on ______ as United States Application Serial No. ______ or PCT International Application No. ______ and was amended on ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate or § 365(a) of any PCT international application(s) designating at least one country other than the United States, listed below and have also identified below, any foreign application(s) for patent or inventor's certificate, or any PCT International application(s) having a filing date before that of the application(s) of which priority is claimed:

Country	Application Number	Date of Filing	Priority Claimed Under 35 U.S.C. 119
Korea	1997-17766	09 May 1997	XX YES ☐ NO
Korea	1997-17767	09 May 1997	XX YES ☐ NO

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

Application Number	Date of Filing

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s) or § 365(c) of any PCT International application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application(s) and the national or PCT International filing date of this application:

Application Number	Date of Filing	Status (Patented, Pending, Abandoned)

I hereby appoint the following attorney and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. **FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P., Reg. No. 22,540**, Douglas B. Henderson, Reg. No. 20,291; Ford F. Farabow, Jr., Reg. No. 20,630; Arthur S. Garrett, Reg. No. 20,338; Donald R. Dunner, Reg. No. 19,073; Brian G. Brunsvold, Reg. No. 22,593; Tipton D. Jennings, IV, Reg. No. 20,645; Jerry D. Voight, Reg. No. 23,020; Laurence R. Hefter, Reg. No. 20,827; Kenneth E. Payne, Reg. No. 23,098; Herbert H. Mintz, Reg. No. 26,691; C. Larry O'Rourke, Reg. No. 26,014; Albert J. Santorelli, Reg. No. 22,610; Michael C. Elmer, Reg. No. 25,857; Richard H. Smith, Reg. No. 20,609; Stephen L. Peterson, Reg. No. 26,325; John M. Romary, Reg. No. 26,331; Bruce C. Zotter, Reg. No. 27,680; Dennis P. O'Reilley, Reg. No. 27,932; Allen M. Sokal, Reg. No. 26,695; Robert D. Bajefsky, Reg. No. 25,387; Richard L. Stroup, Reg. No. 28,478; David W. Hill, Reg. No. 28,220; Thomas L. Irving, Reg. No. 28,619; Charles E. Lipsey, Reg. No. 28,165; Thomas W. Winland, Reg. No. 27,605; Basil J. Lewis, Reg. No. 28,818; Martin I. Fuchs, Reg. No. 28,508; E. Robert Yoches, Reg. No. 30,120; Barry W. Graham, Reg. No. 29,924; Susan Haberman Griffen, Reg. No. 30,907; Richard B. Racine, Reg. No. 30,415; Thomas H. Jenkins, Reg. No. 30,857; Robert E. Converse, Jr., Reg. No. 27,432; Clair X. Mullen, Jr., Reg. No. 20,348; Christopher P. Foley, Reg. No. 31,354; John C. Paul, Reg. No. 30,413; Roger D. Taylor, Reg. No. 28,992; David M. Kelly, Reg. No. 30,953; Kenneth J. Meyers, Reg. No. 25,146; Carol P. Einaudi, Reg. No. 32,220; Walter Y. Boyd, Jr., Reg. No. 31,738; Steven M. Anzalone, Reg. No. 32,095; Jean B. Fordis, Reg. No. 32,984; Barbara C. McCurdy, Reg. No. 32,120; James K. Hammond, Reg. No. 31,964; Richard V. Burgujian, Reg. No. 31,744; J. Michael Jakes, Reg. No. 32,824; Dirk D. Thomas, Reg. No. 32,600; Thomas W. Banks, Reg. No. 32,719; Christopher P. Isaac, Reg. No. 32,616; Bryan C. Diner, Reg. No. 32,409; M. Paul Barker, Reg. No. 32,013; Andrew Chanho Sonu, Reg. No. 33,457; David S. Forman, Reg. No. 33,694; Vincent P. Kovalick, Reg. No. 32,867; and ______. Please address all correspondence to FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P. 1300 I Street, N.W., Washington, D.C. 20005, Telephone No. (202) 408-4000.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full Name of First Inventor	Inventor's Signature	Date
Yong Beom KIM	Yong Beom Kim	99/09/02
Residence: Kunpo-shi, Kyungki-do, Korea		Citizenship: Korea
Post Office Address: 514-1202 Kaya Apt., 1155 Sanbon-dong, Kunpo-shi, Kyungki-do, Korea		

Listing of Inventors Continued on Page 2 hereof. ☐ Yes ☒ No